INSTRUCTION MANUAL

ROWAN

REPRINTED: January 1968

C612/C618/C630/C631/C633

REGATRON®
CONSTANT-CURRENT PROGRAMMABLE POWER SUPPLY

MODEL a633CM

MP MASTER
MA27879

® *Registered U.S. Patent Office. Patents issued and pending.*

E/M

ELECTRONIC MEASUREMENTS

division of THE ROWAN CONTROLLER COMPANY, OCEANPORT, NEW JERSEY 07757

Warranty

Electronic Measurements instruments are guaranteed to be free from defects in material and workmanship for one year from the date of purchase (except for tubes, fuses and batteries). Our liability under this warranty is limited to repairs and adjustments or replacements of defective parts or instruments when the fault is a direct result of defective materials or workmanship in the manufacture of the apparatus. This warranty covers service for the first year, except for transportation to and from the factory. If any fault develops in the equipment, the following steps should be taken:

1. Notify ELECTRONIC MEASUREMENTS. Give full particulars of the difficulty and include the serial number of instrument in question. On receipt of this information, we will give you service information or shipping instructions.

2. On receipt of shipping instructions, forward the apparatus to us, prepaid, and we will make repairs and adjustments immediately at the factory.

3. If the fault has been caused by misuse, or abnormal conditions of operation, as disclosed by our examination, repairs will be billed at cost. In this case, an estimate of the cost will be submitted before work is started.

ELECTRICAL STANDARDS

All company primary standards are either certified directly or are traceable to certification by the National Bureau of Standards.

CLAIM FOR DAMAGE IN SHIPMENT

This instrument received comprehensive visual and electrical inspections before shipment. Immediately upon receipt from the carrier, and before operation, this instrument should be inspected visually for damage caused in shipment. If such inspection reveals internal or external damage in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. When referring to this instrument, always include the model and serial numbers.

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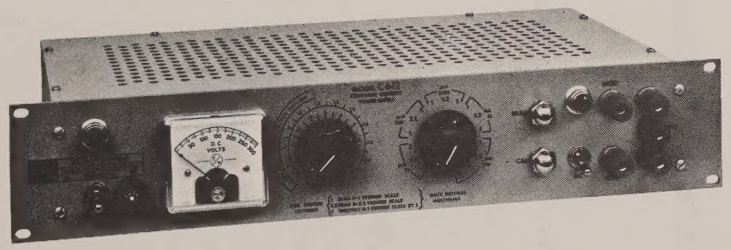

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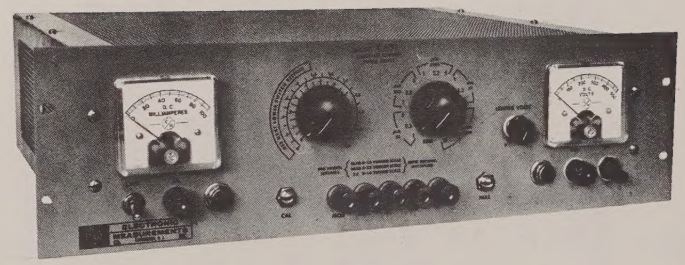

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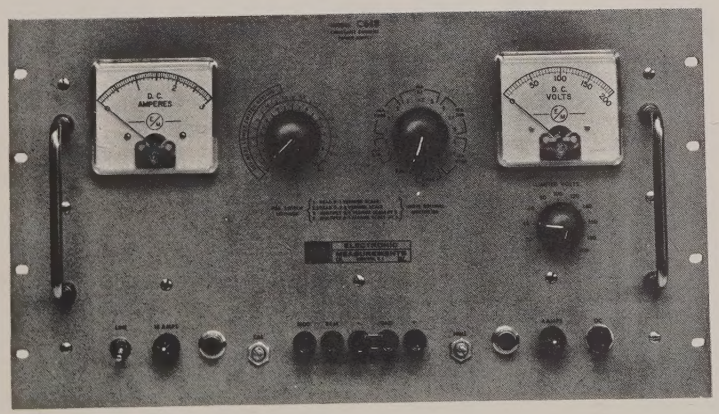

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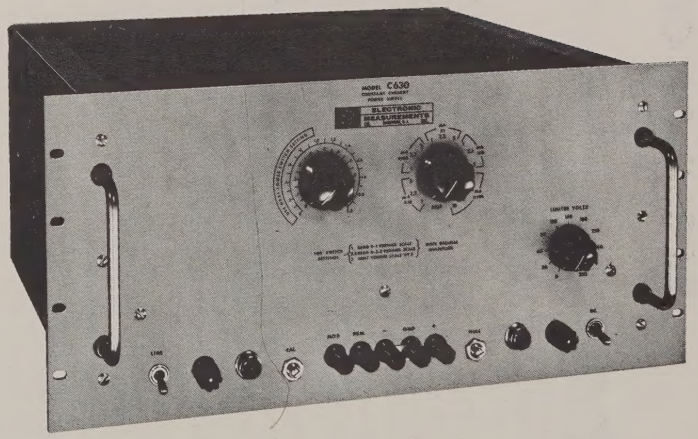


Model C630

Figure 1-1. Typical Regatron Constant-Current Programmable Power Supplies

SECTION 1
DESCRIPTION

1-1. GENERAL CHARACTERISTICS.

This Regatron® Constant-Current Power Supply (see figure 1-1) provides a highly regulated dc output in 16 ranges. Within a selected range, the output is continuously variable from zero to the limit of that range by a front panel control. The output can also be programmed* (remotely controlled) by the use of an external resistor. A panel voltage limiter control (standard, except for C612 and C624) permits control of maximum voltage available for application to the load (range is from zero volts to maximum compliance shown in figure 1-2). The power supply can be mounted in a standard 19-inch rack, or it can be table mounted on rubber feet. On the front panel are a Range Selector switch, a Range Sweep control, current NULL and CAL adjustments, a LIMITER VOLTS control (optional for C612 and C624), a D. C. VOLTS meter, a LINE switch, a DC switch, associated indicator lamps, and FUSE caps. External connections can be made at universal binding posts on the front panel or at a barrier-type terminal strip on the rear of the unit. A swinging link is provided to permit selection of positive or negative ground or floating output.

When specified, the power supply is supplied with chopper stabilization, which provides a constant-current output of exceptional stability. The unit is easily adapted for constant-voltage output by a simple external conversion.

Detailed technical data are given in the Table of Specifications (see figure 1-2).

1-2. APPLICATIONS.

This Regatron power supply can be used in any application where a regulated, constant-current, programmable dc power source of the specified ratings (see figure 1-2) is a requisite. Typical applications follow:

Measurement of peak inverse voltage of solid-state junctions.

Measurement of transistor leakage.

Testing reference diodes for voltage ratings and dynamic impedance.

Providing a dc potential source for transistorized circuits.

Ampere-turn control in the generation of magnetic fields.

Relay testing.

Use as a power source for dc gyrometers and torquers that require precise rpm control.

Checking operating voltage of gas tubes.

Calibrating dc ammeters.

Producing arcs in gaseous breakdown devices.

Forming capacitors.

1-3. STANDARD VERSIONS OF POWER SUPPLY.

Several standard versions of this Regatron Constant-Current Power Supply are available: metered or unmetered; with or without front panel controls; with rear, or front and rear, terminations; and with or without chopper stabilizer. If the LIMITER VOLTS control is supplied with the C612 or C624, either the dc voltmeter or the front terminals must be eliminated.

*Registered U. S. Patent Office.

BASIC MODEL NO.		C612A	C631	C638	C624A	C632	C636	C629	C633	C620	C621	C613	C614	C628	C630	C625	C626	C615	C618
CONSTANT-CURRENT OUTPUT RANGES: Sixteen ranges, zero to range max, available in each range with vernier sweep.		1 ua-100 ma	1 ua-100 ma	0.5ua-100 ma	2.2ua-220 ma	2.2ua-220 ma	2.2ua-220 ma	2.2ua-300 ma	2.2ua-300 ma	5 ua-500 ma	5 ua-500 ma	10 ua-1A	10 ua-1A	10 ua-1A	10 ua-1A	22 ua-2A	22 ua-2A	22 ua-3A	22 ua-3A
VOLTAGE COMPLIANCE	At min. range setting	260	420	2200	260	420	730	210	420	120	170	120	170	220	280	150	190	120	170
	At max. current output	100	300	1500	100	300	600	150	300	50	100	50	100	150	200	75	100	50	100
VOLTAGE LIMITING: zero to compliance max.		OPT.	STD.	STD.	OPT.	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.
PROGRAMMING CONSTANT: micromhos per ma of output		200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
CURRENT REGULATION	LINE	0.15% for line change from 105 to 125V AC (or 198-242 V AC)																	
	LOAD	0.1% for 100 V step change increase or decrease, except 0.2% on 1 and 2.2 ua ranges.																	
RIPPLE & NOISE: 0.04% rms of range setting plus... (See Note)	Neg.Gnd.	0.5ua	0.5ua		0.7ua	0.5ua	1 ua	1 ua	.5 ua	2 ua	2 ua	2 ua	2 ua	4 ua	4 ua	8 ua	8 ua	4 ua	4 ua
	Pos.Gnd.	0.1ua	0.1ua		0.15ua	0.1ua	0.2ua	0.2ua	0.1ua	0.2ua	0.2ua	0.2ua	0.2ua	0.4ua	0.4ua	0.8ua	0.8ua	0.4ua	0.4ua
STABILITY: in % of range selector setting, under fixed line, load, and temp. conditions for 8-hours after warmup	CHOPPER-STABILIZED	0.2% w/internal controls; 0.08% w/suitable external high stability programming resistor																	
	STANDARD	0.3% w/internal controls; 0.15% w/suitable external high stability programming resistor																	
TRANSIENT RESPONSE: Milliseconds required to recover within reg. limits for step change from 0 to 100 or 100 to 0 V.		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
OUTPUT IMPEDANCE		Varies linearly from approx. 30,000 megohms at 1 ua to 30,000 ohms at 3 amperes.																	
MODULATION INPUT: bandwidth constant to 5 kc, with roll-off from 5 kc to 10 kc. MOD input impedance 5000 ohms. (✓=yes)		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
WATTS INPUT POWER: at full load, 125V AC, 60 cps		150	245	1100	175	255	470	190	320	180	200	340	370	525	625	700	760	1000	1175
AMBIENT TEMPERATURE RANGE		Operating 0° to +50°C. Non-operating -40° to +75°C.																	
DIMENSIONS IN INCHES	panel HEIGHT	3-1/2	5-1/4	10-1/2	3-1/2	5-1/4	8-3/4	5-1/4	5-1/4	5-1/4	5-1/4	5-1/4	5-1/4	8-3/4	8-3/4	8-3/4	8-3/4	10-1/2	10-1/2
	panel WIDTH	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
	behind panel DEPTH	9-1/4	15	16-3/4	9-1/4	15	15	15	15	15	15	15	15	15	15	15	15	16-3/4	16-3/4
NET WEIGHT IN LBS. APPROX.		15	40	80	16	40	52	30	40	30	30	45	45	46	46	46	46	77	77

NOTE:

In floating output, ripple exceeds figure specified for positive ground according to character of load and load connections. For 220-volt input, ripple figures are doubled.

FEATURES COMMON TO ALL MODELS:

OVERLOAD PROTECTION. Input ac line and dc output line fused. Safe operation into short circuit load.

CASE GROUND POLARITY. Swinging links for positive or negative ground or floating output.

CONTROLS. Multi-range current selector and sweep vernier. Null and calibration adjustments on panel. All controls wire-wound except voltage limiter.

TERMINATIONS. Front and rear are standard. Front are insulated binding posts (BNC's on C638CM); rear are barrier-type terminal strips. Line cord is 3-conductor type.

FINISH. Smooth gray semi-gloss enamel Class 2 per MIL-A-15090, with black and red panel markings.

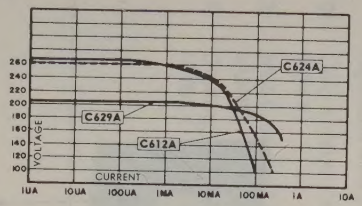
MOUNTING. Units fit standard 19" racks and are equipped with rubber feet for table use.

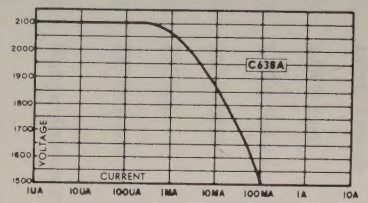
AC INPUT POWER. All models available for either 115 volts ac input, or 220 volts ac input, 50-60 cps single-phase power. The 115-volt version is normally supplied unless 220-volt input is specified.

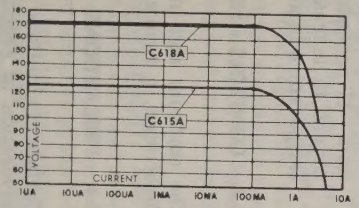
Figure 1-2. Table of Specifications (Sheet 1 of 2)

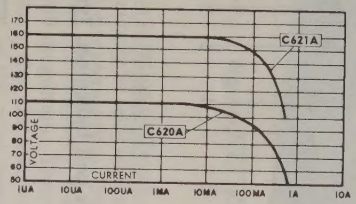
VOLTAGE COMPLIANCE CURVES

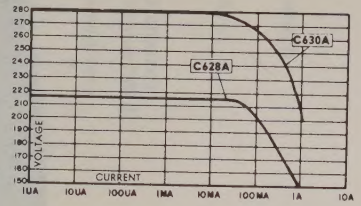
Voltage compliance, defined as the load voltage capability of a constant-current power supply, is analogous to maximum current rating for a voltage regulated unit. These graphs of voltage compliance indicate that actual compliances far exceed the nominal compliances when current output is below maximum.

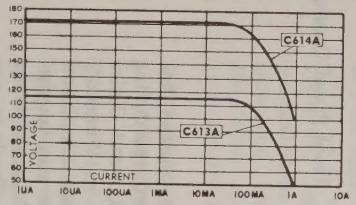


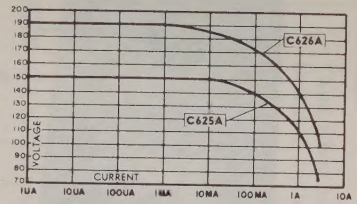


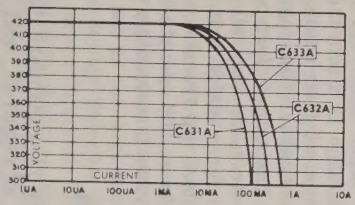


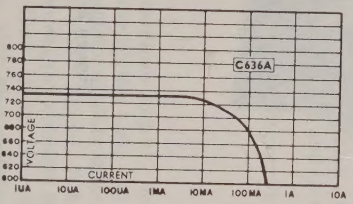












INTERNAL IMPEDANCE VS. OUTPUT CURRENT
at low frequency

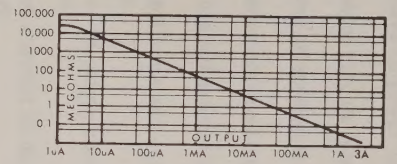


Figure 1-2. Table of Specifications (Sheet 2 of 2)

SECTION 2
OPERATION

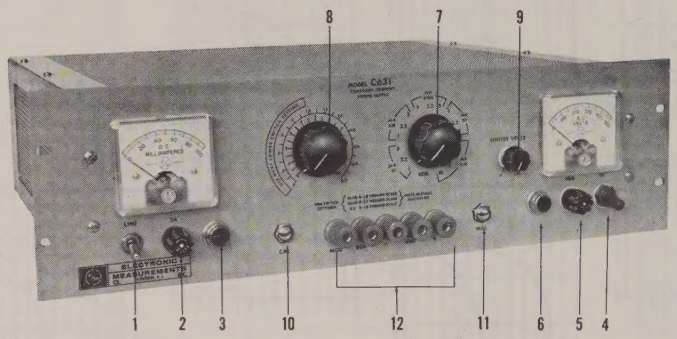


Figure 2-1. Front Panel Controls and Indicators, Typical

2-1. INSPECTION BEFORE USE.

As soon as the power supply has been unpacked, inspect it visually for signs of damage incurred during shipment. If any damage is discovered, read Claim for Damage in Shipment Instructions on Warranty printed inside the front cover of this manual, and follow procedure outlined therein. Before operating equipment for the first time, be sure all shipping blocks have been removed from inside unit. Check to see that all electron tubes and transistors are securely seated in their sockets, and operate all switches and knobs to be sure they function smoothly without binding.

2-2. INSTALLATION.

Mount power supply in a standard 19-inch rack, or place it on a table, as required, near ac input source (refer to Table of Specifications, figure 1-2). Screw holes in each side of front panel provide for securing the unit to a rack, and four rubber feet on the bottom of the unit provide for table mounting.

CAUTION

Sufficient clearance must be provided above and below power supply to insure adequate ventilation. If necessary, remove top and bottom covers to increase ventilation when ambient temperature is above normal.

2-3. CONTROLS AND INDICATORS.

The controls and indicators on the front panel are illustrated in figure 2-1 and explained in figure 2-2.

2-4. PRECAUTIONS.

Certain precautions must be observed to prevent deterioration of regulation at the load when the power supply is operated at very low currents and high load voltages, and to prevent the injection of ripple into the system because of inadequate shielding of load and output lines.

CONTROL OR INDICATOR		FUNCTION
(1)	LINE switch	Used to apply ac power to power supply input.
(2)	LINE fuse	Protects primary input circuit from overloads.
(3)	LINE indicator	Lights when ac power is applied to unit.
(4)	DC switch	Used to switch constant-current output on or off.
(5)	DC fuse	Protects dc output circuit against overloads.
(6)	DC indicator	Lights to indicate that constant-current output circuit is operating.
(7)	Range Selector switch	Used to select one of 16 output current ranges or remote operation.
(8)	Range Sweep control	Used to adjust output current to desired setting within selected range.
(9)	LIMITER VOLTS control (optional with C612 and C624)	Used to control maximum voltage available to load.
(10)	CAL control (screwdriver adjust)	Used, when necessary, to calibrate Range Selector switch knob settings.
(11)	NULL control (screwdriver adjust)	Used, when necessary, to adjust null balance of balanced input detector.
(12)	Binding posts (MOD, (+), GND, (-), REM)	Used to connect power supply to load for local or programmed operation; to make external connections for constant-voltage conversion; to make jumper connections for negative ground, positive ground, or floating output; and to apply modulation input.

Figure 2-2. Controls and Indicators

2-5. Connections to Prevent Deterioration of Regulation at the Load. When the power supply is operated at currents of 1 microampere to 10 microamperes, the shunt resistance between the two interconnecting lead wires must be greater than 100,000 megohms. These lead wires show a leakage resistance that depends on the distance between the wires and on the wire insulation. Whenever voltage is present, leakage current is present, and the leakage current becomes more significant as the load current decreases. For example: if the load current is 10 microamperes and 0.1 percent regulation is desired, the leakage current should be less than 0.01 microampere (0.1 percent of 10 microamperes). To achieve this regulation with 100 volts across the load, the leakage resistance must be greater than 10,000 megohms. Since a safety factor of at least 2 is desirable, the leakage resistance should be greater than 20,000 megohms.

2-6. Prevention of Externally Induced Ripple. Inadequate shielding of load and output lines can lead to the injection of ripple into the system. The ripple is normally greatest when the negative output is grounded. When a spurious signal is coupled into the sample resistor, the regulator amplifier maintains a constant voltage drop across the sample resistor at the expense of the load. The regulator develops a counter signal at the output, and therefore through the load, to cancel the spurious signal. In this way, considerable ripple through the load can be caused by relatively small spurious signals injected into the sample resistor. To prevent ripple, it is of the utmost importance that the negative output lead wire and, when indicated, the load itself be adequately shielded. Shielding, must also be considered when the power is connected to an ac-line-operated device.

2-7. SELECTION OF CURRENT RANGE, PREFERRED METHOD.

When a wide current sweep or output in the 0- to 1- or 2.2-milliampere range is desired, the Range Sweep control can be set to any position. However, it is usually advisable to use the lowest Range Selector switch setting consistent with the desired output current, and to keep the Range Sweep control setting at the high end of the scale. This method is recommended because better regulation is obtained with the Range Sweep control set at the high end of the scale. For example: if the Range Selector switch is set at the low end of the scale (marked USE NEXT LOWER SWITCH SETTING) to obtain an output of 16 milliamperes. In this case, the Range Selector switch should be set at MA X10-2.2 and the Range Sweep control position should be set as required at the high end of the scale to obtain the 16-milliampere output.

NOTE

Before operating the power supply, read paragraphs 2-4 through 2-7 carefully.

2-8. LOCAL OPERATION.

Proceed as follows to operate the power supply using front panel controls:

a. Be sure that LINE and DC switches are set to off position.

b. Plug line-cord power connector into ac power source.

c. Set LINE switch to on position. LINE indicator lamp should light.

d. Connect load between (+) and (-) output binding posts.

e. Set Range Selector switch for desired current output range (refer to paragraph 2-7).

CAUTION

Be sure Range Sweep control is set below desired output current value.

f. With DC switch off, set LIMITER VOLTS control to desired maximum voltage as indicated by D. C. VOLTS meter.

NOTE

Model C612 or Model C624 may or may not be supplied with a LIMITER VOLTS control. The purpose of the LIMITER VOLTS control is to prevent an uncontrolled rise in voltage applied to the load above a specific value. However, when the LIMITER VOLTS control is set for a particular value, a rise in load resistance above the "knee" of the applicable EI curve causes a decrease in output current to below the value for which the power supply current controls are set. Effectively, the power supply becomes a constant voltage source with only moderate regulation.

g. Set DC switch to on position. DC indicator lamp should light.

h. Set Range Sweep control for desired current value. Panel voltmeter will indicate voltage across load plus voltage drop across internal sample resistor.

2-9. PROGRAMMED OPERATION.

The power supply output can be programmed (remotely controlled) by the use of an external resistor. A fixed resistor can be used to provide constant-current output, a series of switch-selected resistors can be used to provide discrete currents, or nonlinear potentiometers can be used to provide various waveforms.

The programming constant for a constant-current power supply is better expressed in conductance than resistance. The constant for this power supply is 200 micromhos per milliampere of output current with the Range Sweep control set at maximum. Five thousand ohms equal 200 micromhos, so a 5,000-ohm resistor allows for a 1-milliampere output. The addition of another 5,000-ohm resistor in parallel adds another milliampere to the output for a total of 2 milliamperes. The programming resistor must have an adequate power rating. Actual wattage is expressed as: power dissipation in watts equals 5 times the load current in amperes. A safety factor of approximately 3 to 1 is recommended.

For programmed operation, set Range Selector switch to REM, and connect programming resistor between REM and (-) binding posts. (See figure 2-3.) Because load current flows through programming resistor, it is not necessary to run two lead wires to (-) binding post if programming resistor is physically located near load. A common negative line to load and programming resistor can be used. However, because (-) binding post is also sensing point, negative line must be well shielded and one end of shield must be connected to REM binding post.

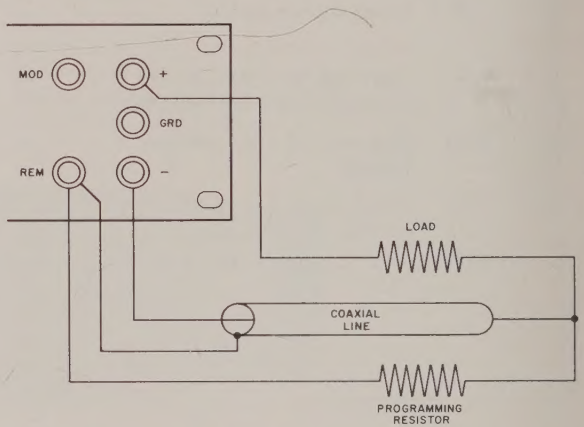


Figure 2-3. Programmed Operation

2-10. OPERATION FOR CONSTANT-VOLTAGE OUTPUT.

This constant-current power supply can be converted for constant-voltage output by the external connections shown in figure 2-4. The constant-voltage configuration provides an output as low as 5 volts with regulation of 0.05 percent. Proceed as follows:

a. Set Range Selector switch to MA X1-1.

b. Turn Range Sweep control to maximum clockwise setting.

c. Select control resistor of appropriate value for desired output voltage. Value of resistor is determined by approximately 1,000-ohms-per-volt constant when Range Selector switch is set to MA X1-1 (see schematic diagram). If exactly 1000 ohms per volt is required, recalibrate (refer to paragraph 5-4). Output voltage is equal to resistance value divided by 1,000 and added to Range Sweep control setting, or 5 volts.

d. Connect resistor between (+) and (-) binding posts.

e. For C612 or C624 only, connect one end of appropriate fuse (see figure 2-4) to (+) binding post. Then (for all models) connect load between free end of fuse and REM binding post.

f. Vary output voltage, as required, by adjusting Range Sweep control or by changing value of control resistor (refer to c above).

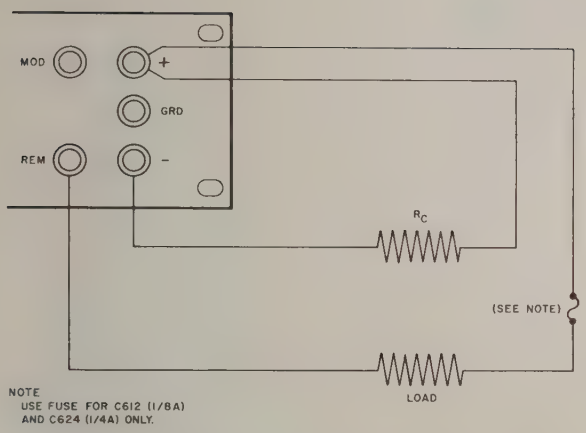


Figure 2-4. Constant-Voltage Conversion, External Connections

2-11. OPERATION WITH MODULATION.

To keep the current constant, the voltage drop across a sample resistor is kept constant. The load current goes from the plus terminal, through the load, to the negative terminal and through the sample resistor to the internal common of the power supply. This internal common is brought out of the unit through the REM terminal.

The voltage drop across the sample resistor is compared to a fixed reference voltage by the balanced input detector. The error voltage, which is amplified and applied to the series regulator tubes, is phased to develop a counter error large enough to offset the original error. Thus, constant voltage across the fixed sample resistor means constant current through the sample resistor. Because the load current flows through the load resistor and the sample resistor, and there are no current sinks or sources in the circuit, the load current is also constant.

If the reference voltage is varied, as when the Range Sweep control is rotated, the voltage drop varies across the sample resistor, and the current in the sample resistor varies correspondingly. There are two ways to vary the current. One is to vary the reference voltage, as indicated above; the other is to vary the sample resistance. Either or both methods may be used.

Modulation is varying of the reference voltage. A resistor is placed in series between the reference grid of the difference amplifier and the arm of the Range Sweep control potentiometer. If a signal is placed across this series resistor, the voltage developed adds or subtracts, as the case may be, from the reference voltage. The current increases or decreases, as indicated. For low frequencies, the amplifier is capable of following the reference changes with the output current. Thus if a 1-volt peak-to-peak signal is placed on the reference voltage, with the Range Sweep control potentiometer set to maximum setting (nominal 5 volts), the output current will vary from 95% of nominal to 105% of nominal.

As the modulating frequency increases, the amplifier is less capable of keeping the output current in phase with the modulating signal, and a phase shift develops. Also, the transconductance of the unit falls off. Eventually, at higher frequencies, there is a large phase shift, and the variation in current is only a small percentage of what it would be if the amplifier could handle the higher frequencies.

Certain precautions must be observed. One is the above-indicated frequency dependency. A second is the method by which the modulating signal is applied. One side is connected to the MOD terminal, and there is no dc isolation (capacitor) between the MOD terminal and the reference grid. Thus, the MOD terminal is always at the same potential as the reference. The other side of the signal is applied to the REM terminal, which is the internal common of the power supply. The arm of the Range Sweep control is tied to the internal common through a 25-uf, 25-volt capacitor. Thus, the load for the modulating signal is a 4.7K-ohm resistor in series with a 25-uf capacitor and at a different dc potential from either the plus output or the negative output. The modulating signal generator must be sufficiently isolated from the output terminal potential to prevent any kind of dc loop that may cause improper operation of the unit.

The balanced input detector is designed to operate with a voltage of 0 to 5 volts on both control grids. If the grid voltages are excessive, nonlinearities may result. It is recommended that the modulating signal plus the setting of the Range Sweep control never go beyond the 0- to 8-volt band.

As an alternate, an audio transformer can be wired directly across the 4.7K-ohm resistor and the modulating signal put on the transformer.

This power supply has been tested for a maximum modulation frequency of 10 kc. The modulation source should have dc isolation if its output impedance is more than 1,000 ohms. The maximum permissible amplitude of modulation is limited by the voltage on the reference grid of the power-supply balanced input detector; this voltage is determined by the Range Sweep control setting. Exceeding the limit thus established will cause progressive loss of control by the current regulation system.

Connect modulation source between the REM and MOD binding posts. At maximum Range Sweep control setting, do not exceed 6 volts peak-to-peak signal input. Maximum modulation is permissible at a Range Sweep control setting of 80 percent of maximum; at this point, 8 volts peak-to-peak is permissible. The permissible peak-to-peak signal input decreases proportionately to zero at low end of the Range Sweep control scale. Nonlinear modulation signals should conform to peak-to-peak values specified above.

CAUTION

Ratings of the power supply should not be exceeded during any portion of the modulating signal.

SECTION 3
APPLICATIONS

3-1. MAGNETIC FIELD APPLICATIONS.

A constant-current power supply can be used to set and maintain a magnetic field. Magnetic flux density is a function of the number of turns of wire and the current in each turn. When a constant-voltage supply is used, the magnetic field becomes a function of the temperature of the magnet wire and, as the wire changes temperature, the resistance varies and the current and the magnetic field vary. If a constant-current power supply is used, the voltage changes as the resistance changes, and the current remains constant. The magnetic field, therefore, is unaffected by variations in magnet wire temperature.

The modulation capability of the constant-current power supply offers an additional degree of sophistication. By sensing the magnetic field, supplying the sensed information to a comparator, and using the comparator to modulate the constant-current power supply, a closed-loop control system can be devised. Figure 3-1, for example, shows a device that maintains a constant over-all magnetic field when several magnetic fields are involved (some of which may vary). Lever arm A, which is magnetic, is pivoted at one end and held by a spring at the other end. The spring tension determines the position of the arm and thereby the strength of the magnetic field. A linear potentiometer, also attached to the arm, is connected to a comparator, which measures the resistance of the potentiometer and therefore the position of the lever arm. Any change in location of the arm is transmitted to the comparator through the potentiometer, and the resultant corrective voltage is fed to the modulation input of the power supply. Thus, as individual magnetic fields vary, the system keeps the over-all magnetic field constant.

A constant-current power supply may also be used to control the precessing of a gyro. Gyros can be precessed by a magnetic field, and a constant-current power supply, with modulation, can control a magnetic field. By using a circuit similar to that shown in figure 3-1, the rate of precessing can be adjusted and controlled.

3-2. CHECKING OPERATING VOLTAGE OF GAS TUBES AND REFERENCE DIODES.

Most gaseous devices, such as VR tubes, require a firing potential higher than the operating potential. Constant-voltage power supplies can be used, but they are frequently cumbersome and require more accessory equipment than constant-current power supplies.

To operate a gaseous device at fixed current using a constant-current power supply, simply set the power supply to the desired current. Output voltage will rise to the value required to fire the tube and then drop back to the operating voltage. Figure 3-2 shows a simple method of sorting reference tubes according to operating voltage at a given current. The constant-current power supply is set for the required current and a tube is inserted in test position. The power supply LINE switch is set to the on position and the tube is fired. Operating voltage is read from the voltmeter, and the tube is classified according to its voltage. This procedure can be adapted for more complicated tests. For example, if a life run is required to determine tube voltage changes with time, the power supply can be left on and tube voltage readings taken periodically. If the temperature is cycled, the temperature coefficient can be calculated from voltage readings.

Another test adaptation can be used to determine ac impedance. The modulation feature of the constant-current power supply makes this a simple test. Using a set-up identical to that shown in figure 3-2, except for the use of an ac voltmeter, the current supply is modulated by a known signal so that the output current has a known degree of modulation about its dc base. The ac impedance is the ac voltage across the reference tube divided by the modulation current.

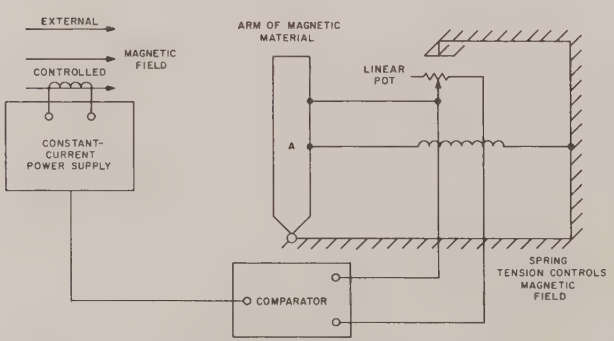


Figure 3-1. Set-up for Maintenance of Constant Over-all Magnetic Field When Several Fields are Involved

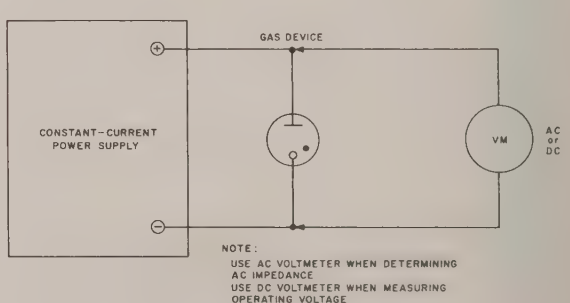


Figure 3-2. Method of Sorting Reference Tubes

The operating voltage of a reference diode is checked in the same way as the operating potential of a VR tube. Similar information is required in both cases. The only difference is in the size and range of values; reference diodes are available in many more voltage and current ranges than VR tubes. The procedure for determining ac impedance of reference diodes is similar to the procedure used for VR tubes.

3-3. MEASUREMENT OF PEAK INVERSE VOLTAGE OF SOLID-STATE JUNCTIONS.

Constant-current power supplies are of great value in testing semiconductor devices. The determination of PIV (peak inverse voltage) is difficult with a constant-voltage supply. A junction is usually specified by maximum leakage current at a specific voltage, which is the PIV. If a constant-voltage supply is used, an ammeter, a voltmeter, and a resistor in series with the junction and the voltage supply are required. With a constant-current power supply, it is necessary to have only a voltmeter across the junction. The supply is set for maximum leakage current, the junction is connected across the supply, and the voltage drop is observed on the voltmeter. By recording the voltage, the junction can be classified according to PIV. For example, assume that the junctions (see figure 3-3) are to be classified at 50-volt intervals. The diode is connected in the circuit, the power supply is turned on, and the voltmeter indication rises to 75 volts. In this case, the diode is classified as having a PIV of 50 volts. This procedure can be completely automated so that the junctions are sorted automatically.

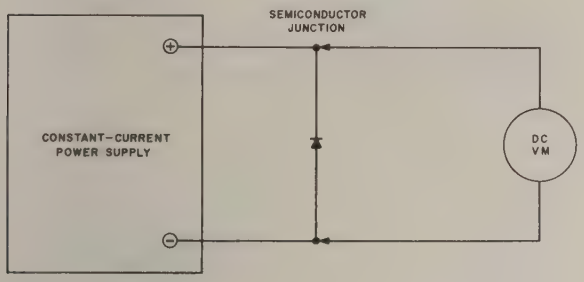


Figure 3-3. Checking PIV of Semiconductor Diodes

The forward drop test is also easily performed with a constant-current power supply, using the same circuit, but connecting the diode in the forward direction. The only difference is in the size of the values determined. Usually the PIV is a large value and the leakage current a small value, while the forward voltage drop is a small value and the forward current a large value.

3-4. TESTING RELAYS.

Many relays require little sophistication in the power supplies used to operate and test them. However, in the case of finely balanced relays where the coil current must be closely controlled, a constant-current power supply is recommended. For example, the constant-current power supply can easily be used when latch current and release current must be determined precisely. A constant-voltage supply would require an ammeter, but the calibrated constant-current supply requires no external meters.

Figure 3-4 shows a typical relay test device, where a programming potentiometer is driven by a reversible motor. Current in the relay under test is recorded. Then the motor is energized, and the current begins to increase. The relay under test closes, causing the motor to reverse, and the current begins to decrease. When the releasing current value is reached, the test relay opens, and the motor again reverses, causing the current to increase. This cycle continues and the current is continuously recorded for as long as desired.

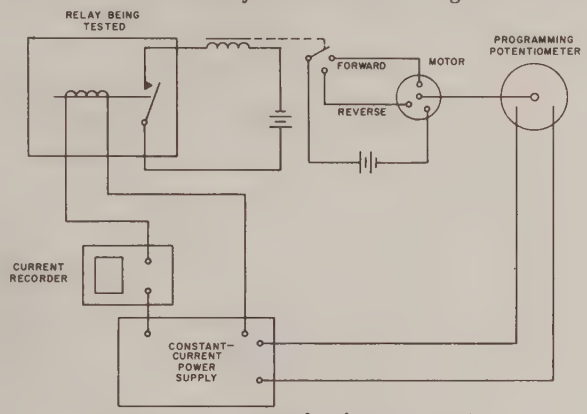


Figure 3-4. Typical Relay Test Device Using Constant Current

3-5. MISCELLANEOUS APPLICATIONS.

Constant-current power supplies can be used in generating and maintaining an accurate, stable voltage source. Most solid-state types of reference are preferably driven by a current source. If a reference diode is powered by a regulated, stabilized constant-current power supply, the voltage across the diode remains accurate and stable.

Constant-current power supplies can be used in the field of electroplating. Since plating is mechanically a process of depositing charged ions of metal on the surface of another type of metal, the number of charged ions deposited in a specific length of time must be known to control the thickness of the plating. The number of ions deposited can be determined by the length of time the associated constant-current power supply has been in operation. Especially when plating with precious metals, the amount of metal deposited is extremely important. If a constant-current power supply is used, is necessary only to use a timer during the plating process so the amount of metal deposited can be accurately computed and controlled.

In capacitor forming, a low current must be run through the capacitor. As the film is formed, the voltage increases, and it is usually desirable to keep the current constant while the voltage rises to a predetermined value. A constant-current power supply, with voltage limiter set to maximum, keeps the current constant as the voltage rises until the maximum voltage is reached. Then the voltage begins to stabilize, and the current diminishes.

The same technique is used in charging special batteries as in forming capacitors. A constant-current power supply, with voltage limiter, can be used without constant monitoring to maintain a specific current until the battery voltage is reached.

SECTION 4
CIRCUIT DESCRIPTION

NOTE

All schematics in this section have been simplified to show only essential functional circuit elements.

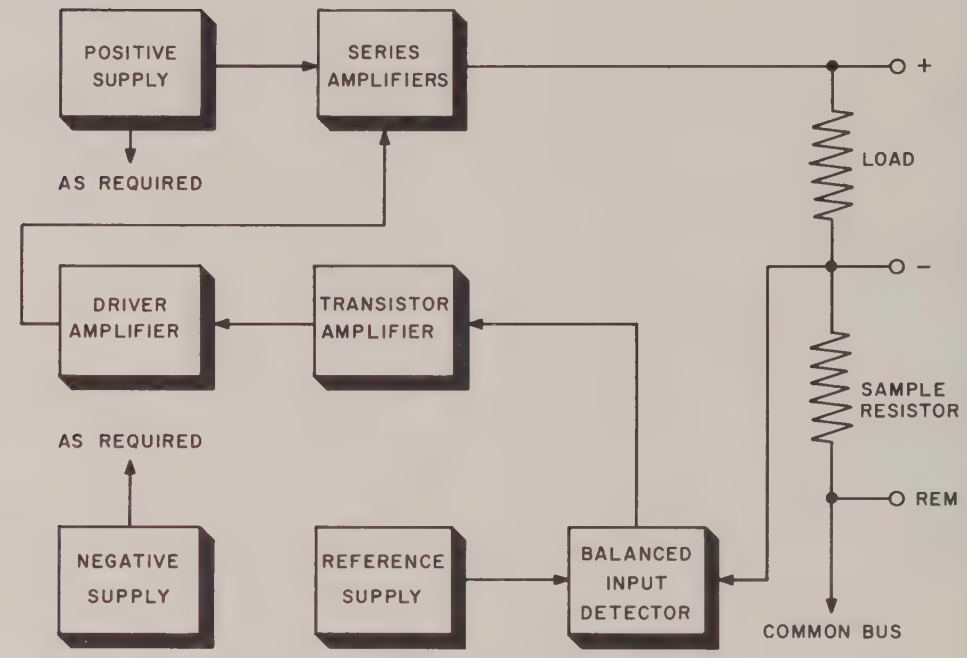


Figure 4-1. Functional Block Diagram, Typical Regatron Constant-Current Power Supply

4-1. BLOCK DIAGRAM THEORY. (See Figure 4-1.)

Basically, the power supply consists of seven circuits, as shown in figure 4-1. These circuits function to maintain a constant voltage drop across the fixed sample resistor in series with the external load. Because the voltage across the sample resistor remains constant, the current through the resistor, and consequently through the load, also remains constant. The balanced input detector compares the voltage across the sample resistor with a stable reference voltage. Any difference between the two develops an error signal at the output of the detector. This signal is amplified and then applied, through the transistor amplifier and the driver amplifier, to the series amplifiers. The resultant change in output of the series amplifiers changes the current through the sample resistor, and therefore in the load, so that the error is reduced to zero and the rated output is maintained.

4-2. BALANCED INPUT DETECTOR CIRCUIT.

Pin 2 of balanced input detector V_A (see figure 4-2) is connected to the arm of Range Sweep control R_A, and pin 7, the sampling grid, is connected to the arm of Range Selector switch S_A. Any difference between the voltages on the two grids is amplified and appears as an error signal at the plates. Zener diode CR_A maintains a stable 5-volt drop across the Range Sweep control. The Range Selector switch connects the selected sample resistor into the circuit. Regulated plate voltage for the balanced input detector is taken from VR tube V_B and the cathodes are returned to -150 volts regulated by VR tube V_C. NULL control R_B is used for initial null balancing of the input detector. Diode CR_B prevents triggering of the unit into a stable on condition (maximum output voltage). Capacitor C_A serves as a filter to block ac components from the reference grid.

4-3. TRANSISTOR AMPLIFIER AND DRIVER AMPLIFIER. (See figure 4-3.)

Any error signal developed and amplified by the balanced input detector is applied to transistors Q_A and Q_B. This transistorized amplifier stage is required to bias driver amplifier V_D with a negative dc voltage. Because the error signal from the balanced input detector fluctuates around a positive dc base, the base must be converted to negative dc. The conversion is accomplished by direct coupling. PNP transistors Q_A and Q_B, which use a negative collector voltage, serve as effective direct-coupling devices in this application, as well as amplifiers.

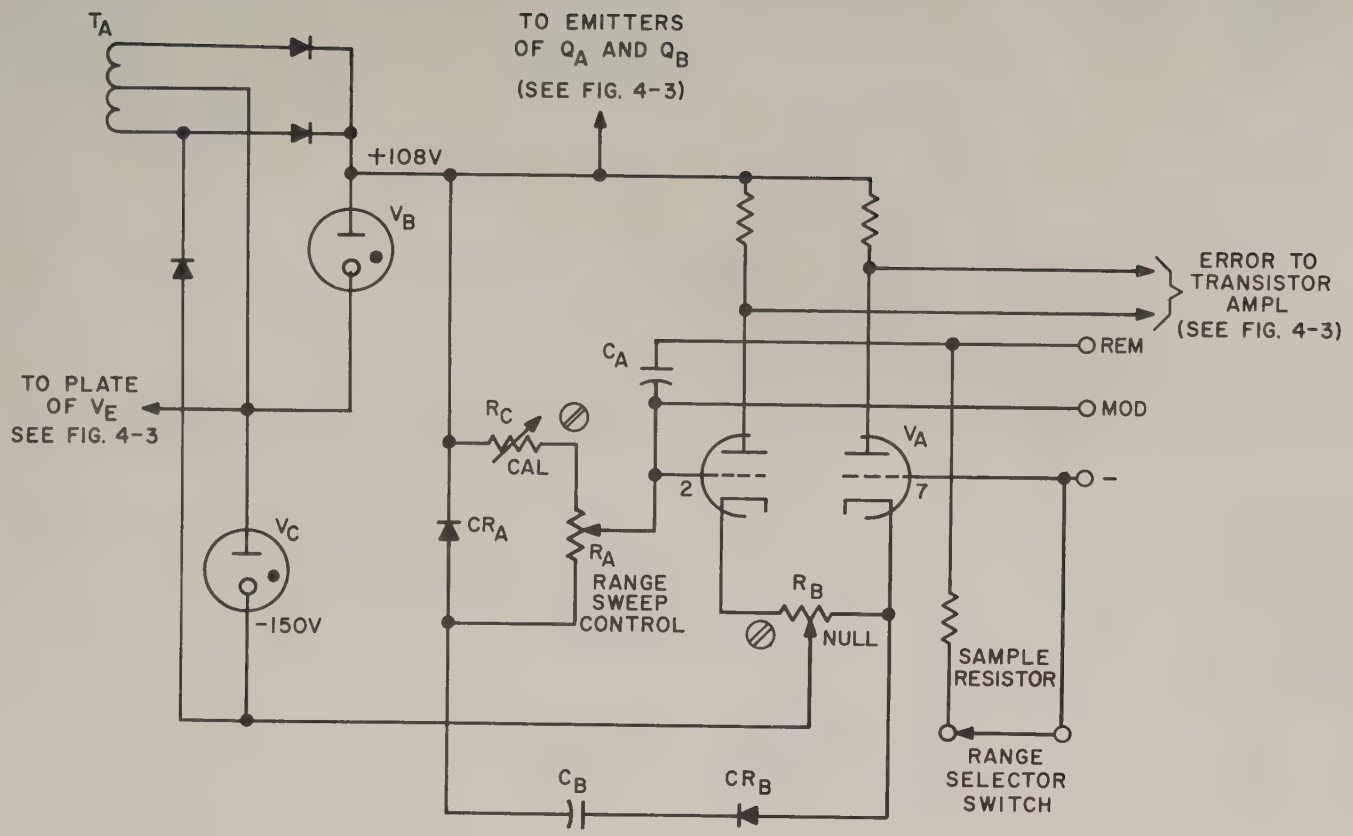


Figure 4-2. Balanced Input Detector, Simplified Partial Schematic

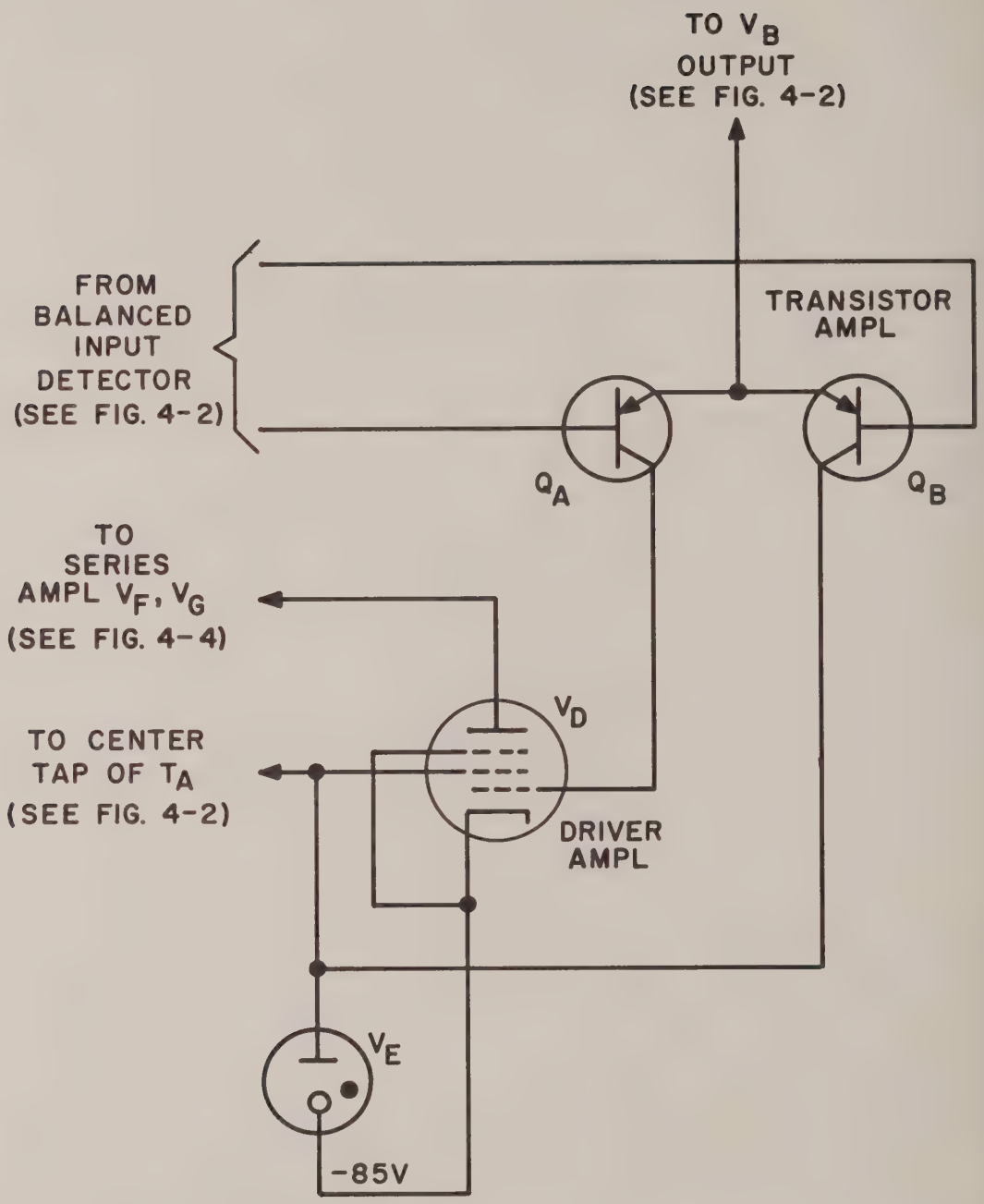


Figure 4-3. Transistor Amplifier and Driver Amplifier, Simplified Partial Schematic

Amplifier V_D provides high gain. The amplified error signal from V_D is applied to the control grids of the series amplifiers. Because the power supply is designed to start at a very low output, the output of the driver amplifier must reach approximately -45 volts to cut off the series amplifiers. The cathode of V_D is returned to -85 volts, regulated by VR tube V_E, so that there will be adequate voltage across the tube at cutoff.

4-4. SERIES AMPLIFIER. (See figure 4-4.)

Paralleled beam power tubes V_F and V_G are used as series amplifiers, or variable conductances. The control grids are direct-coupled to the output of driver amplifier V_D. (In some models, there is a cathode follower between the driver amplifier and the series amplifiers. The output of the driver amplifier is direct-coupled to the control grids of the cathode follower,

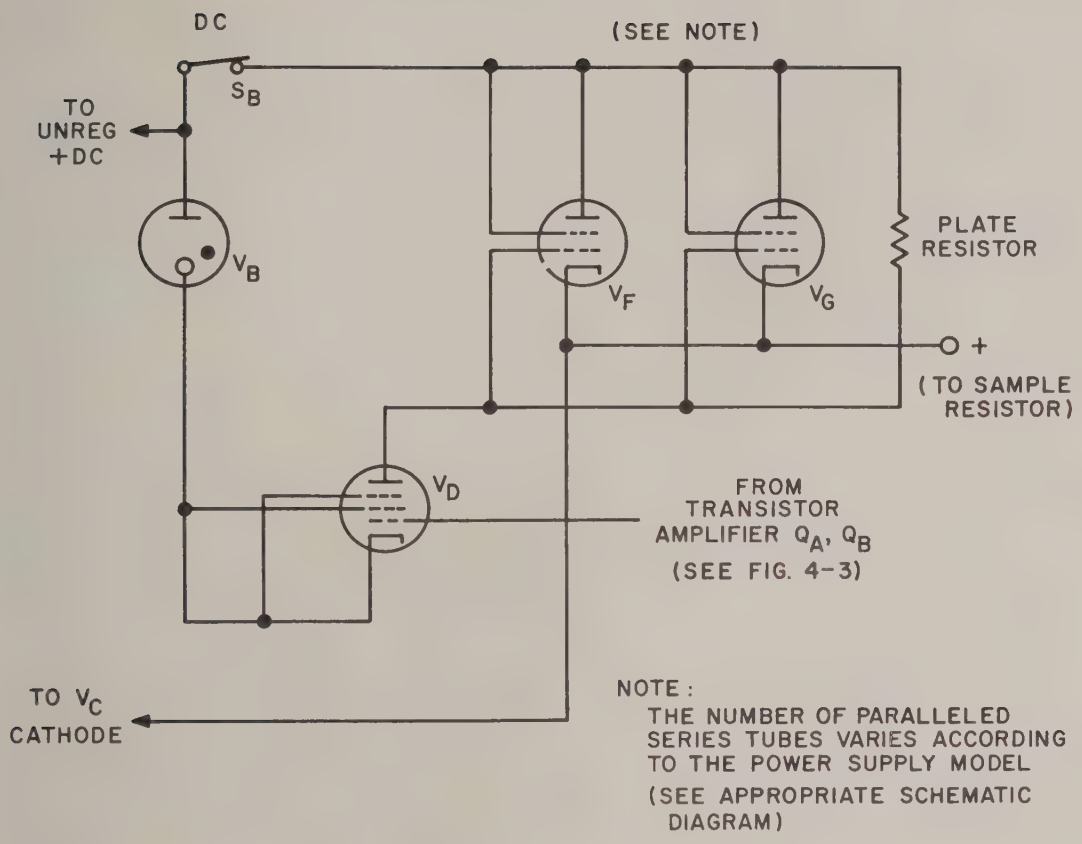


Figure 4-4. Series Amplifier Circuit, Simplified Partial Schematic

and the control grids of the series amplifiers are direct-coupled to the cathode follower.) Any error voltage at the series amplifier control grids varies the tube conductance. Thus, an increase in error voltage causes conductance of the series amplifiers to decrease. Since these amplifiers are connected in series between the unregulated positive supply and the positive output to the sample resistor, the voltage drop across the tubes increases, causing a decrease in available output voltage and a consequent decrease in current through the sample resistor. A decrease in error voltage causes a corresponding increase in conductance of the series amplifiers and a consequent increase in current through the sample resistor.

4-5. POSITIVE AND NEGATIVE SUPPLIES.

(See figure 4-5.)

Transformer T_A supplies stepped-up voltages for all the rectifiers and plate and filament voltages for all electron tubes in the power supply.

The positive supply uses silicon diodes CR_C through CR_F for full-wave rectification, with filtering by resistor R_D and capacitor C_C. This supply delivers unregulated positive plate voltage for the series amplifiers and a positive service potential for the plate of amplifier V_D and the control grids of the series amplifiers. The rectified, filtered voltage is also supplied through resistor R_E to VR tube V_B so a preregulated stepped-down voltage is supplied to the plates of balanced input detector V_A and the common emitters of amplifiers Q_A and Q_B. (A time-delay relay is included in the input circuit of some models in conjunction with an additional transformer that feeds special rectifiers which supply plate voltage for tubes V_D, V_F, and V_G.)

The negative supply uses a half-wave rectifier consisting of silicon diodes CR_G, CR_H, and CR_I. The rectifier output is filtered by capacitor C_D, dropped to -150 volts by resistor R_F, and preregulated by VR tube V_C. The negative potential is then dropped to -85 volts by resistor R_G and further regulated by VR tube V_E. The regulated negative voltages are used in the return circuits for balanced input detector V_A, transistor amplifier Q_A, and driver amplifier V_D to improve the over-all operating range. Capacitor C_E blocks any high-frequency ac components generated by the VR tubes from the driver amplifier screen grid.

NOTE

Models C612 and C624 have three gas regulator tubes (V_B, V_C, and V_E). All other models have five gas regulator tubes.

Ac filament voltages are supplied directly by a transformer secondary.

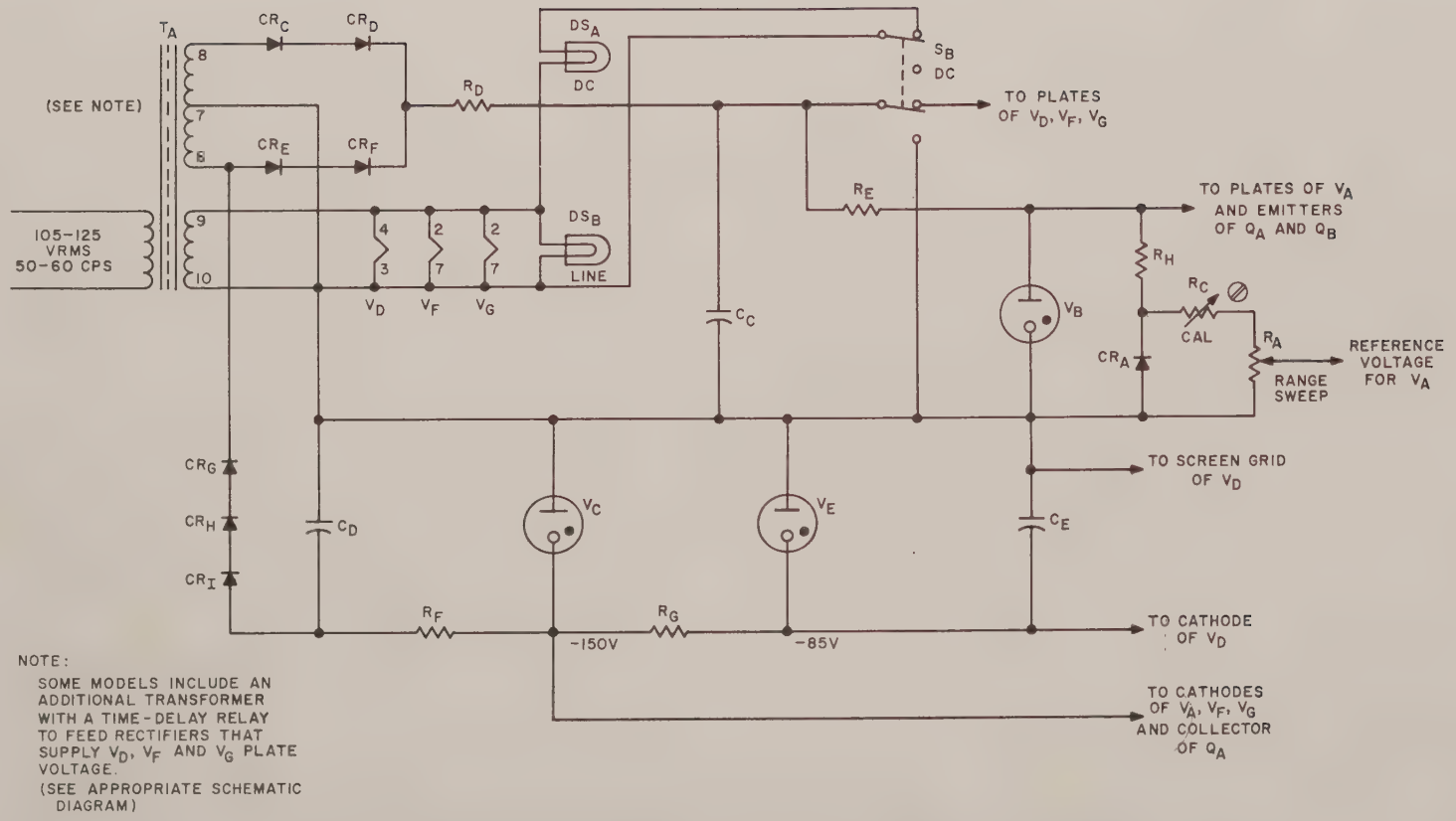


Figure 4-5. Positive and Negative Supply Circuits, Simplified Partial Schematic

4-6. REFERENCE SUPPLY. (See figure 4-5.)

The preregulated positive voltage (refer to paragraph 4-5) is further dropped by resistor R_H and stabilized at approximately 5 volts by Zener diode CR_A to serve as the reference voltage for balanced input detector V_A. CAL control R_C permits calibration of the control system for a precise output current based on the exact potential across CR_A. The CAL control also permits periodic calibration to compensate for errors due to aging of the Zener diode and its associated components.

4-7. FILAMENT REGULATOR.

The filaments of balanced input detector V_A are regulated by a transistorized circuit that includes power transistor Q_C and signal transistors Q_D and Q_E. Regulation of the tube filament voltage is necessary because the tube characteristics vary greatly over the operating range generated by line input variations. Transistor Q_E is used as an error detector, with emitter referenced to the voltage across Zener diode CR_J. Any error signal is applied to transistor Q_D, which drives transistor Q_C to reduce the error towards zero. The regulated filament voltage can be adjusted over a small range by potentiometer R_J.

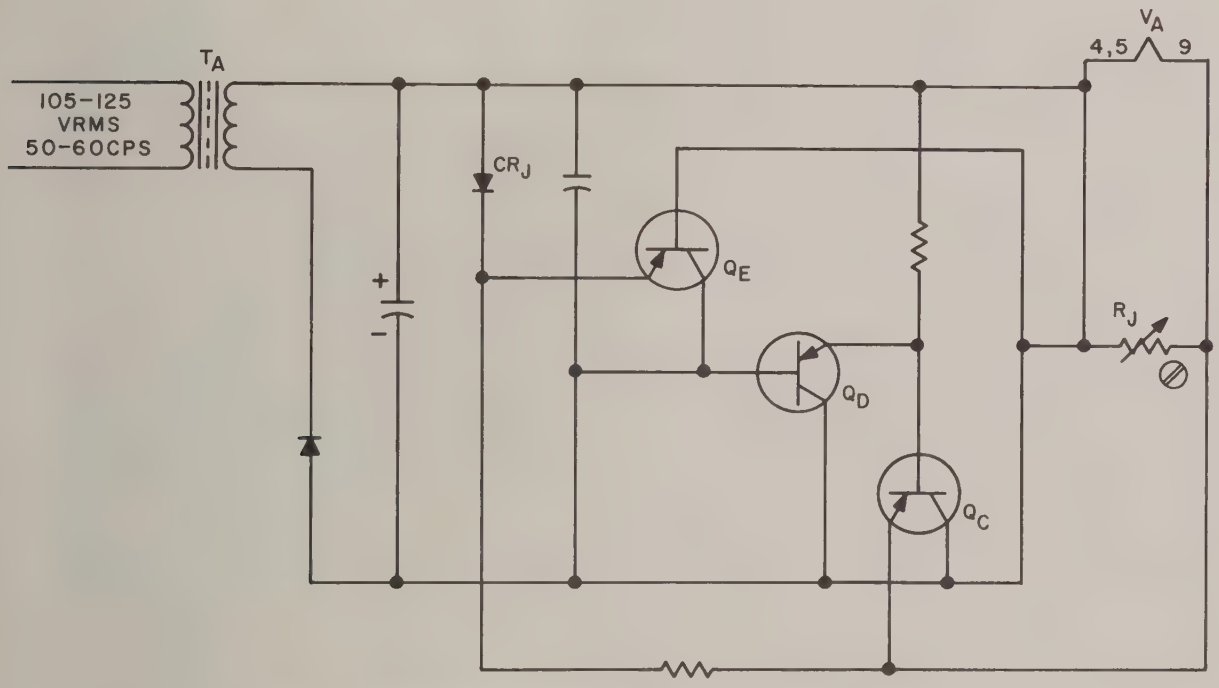


Figure 4-6. Filament Regulator Circuit, Simplified Partial Schematic

4-8. VOLTAGE LIMITER.

On models so equipped, the voltage limiter permits control of the maximum voltage available for application to the load.

The voltage limiter (see figure 4-7) incorporates a bridge-like sensing device similar to that used in EMC voltage-regulated power supplies. MAX CAL control R_L permits calibration to rated maximum voltage. Potentiometer R_K is somewhat higher than the value actually required to develop the rated maximum voltage compliance, because the potentiometer has been selected to develop the full voltage of which the power supply is capable. This voltage is higher than the rated maximum compliance.

The base of transistor Q_G senses a portion of the output voltage at the junction of the LIMITER VOLTS control and MAX CAL potentiometer. The signal at the emitter follows the voltage fluctuation sensed at the base in approximately a 1 to 1 ratio, and the signal is applied to the emitter of transistor Q_F. The base of transistor Q_F is connected to the power supply REM line through ZERO ADJ potentiometer R_M, and the transistor compares the voltage at the REM terminal with the voltage sensed at the junction of the LIMITER VOLTS control and the MAX CAL potentiometer. The resultant collector signal is applied, through diode CR_K to the control grid of high-gain amplifier V_D.

When the output voltage falls below the value set by the LIMITER VOLTS control, the sensed voltage applied to the emitter of transistor Q_F is negative with respect to the voltage at the base, which is at REM line potential; transistor Q_F therefore does not conduct; and diode CR_K is turned off and has no effect on the control grid of high-gain amplifier V_D. When the

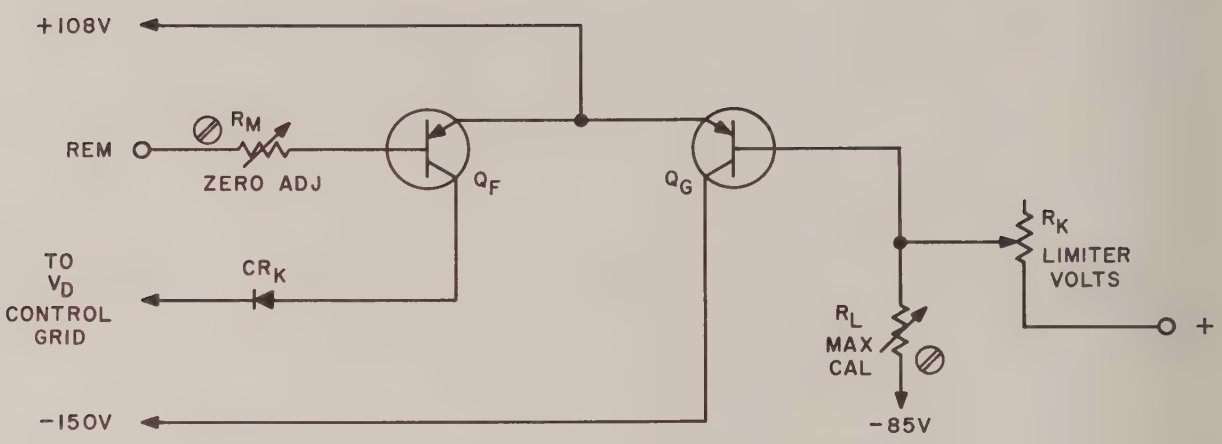


Figure 4-7. Voltage Limiter Circuit, Simplified Partial Schematic

output voltage rises to the value set by the LIMITER VOLTS control, the sensed voltage applied to the emitter of transistor Q_F becomes more positive than the voltage at the base. Transistor Q_F and diode CR_K conduct, and the limiter signal is applied to the control grid of V_D, thus driving the power supply regulator system to equilibrium at the voltage limiter setting. ZERO ADJ. potentiometer R_M permits setting the voltage limiter for zero difference between the REM line and the sensed voltage when the regulator system is at equilibrium.

4-9. CHOPPER STABILIZER. (See figure 4-8.)

On models so equipped, the chopper stabilizer unit continuously corrects for zero offset in balanced input detector V_A, thereby eliminating output drift. Connected across the grids of detector V_A, the chopper continuously samples the offset at pin 7 and chops it at K_A to produce a square wave, which is amplified and rectified through V_H. The output of V_H is filtered, and the resultant correction signal is applied to pin 2, thereby reducing the net offset to a negligible value.

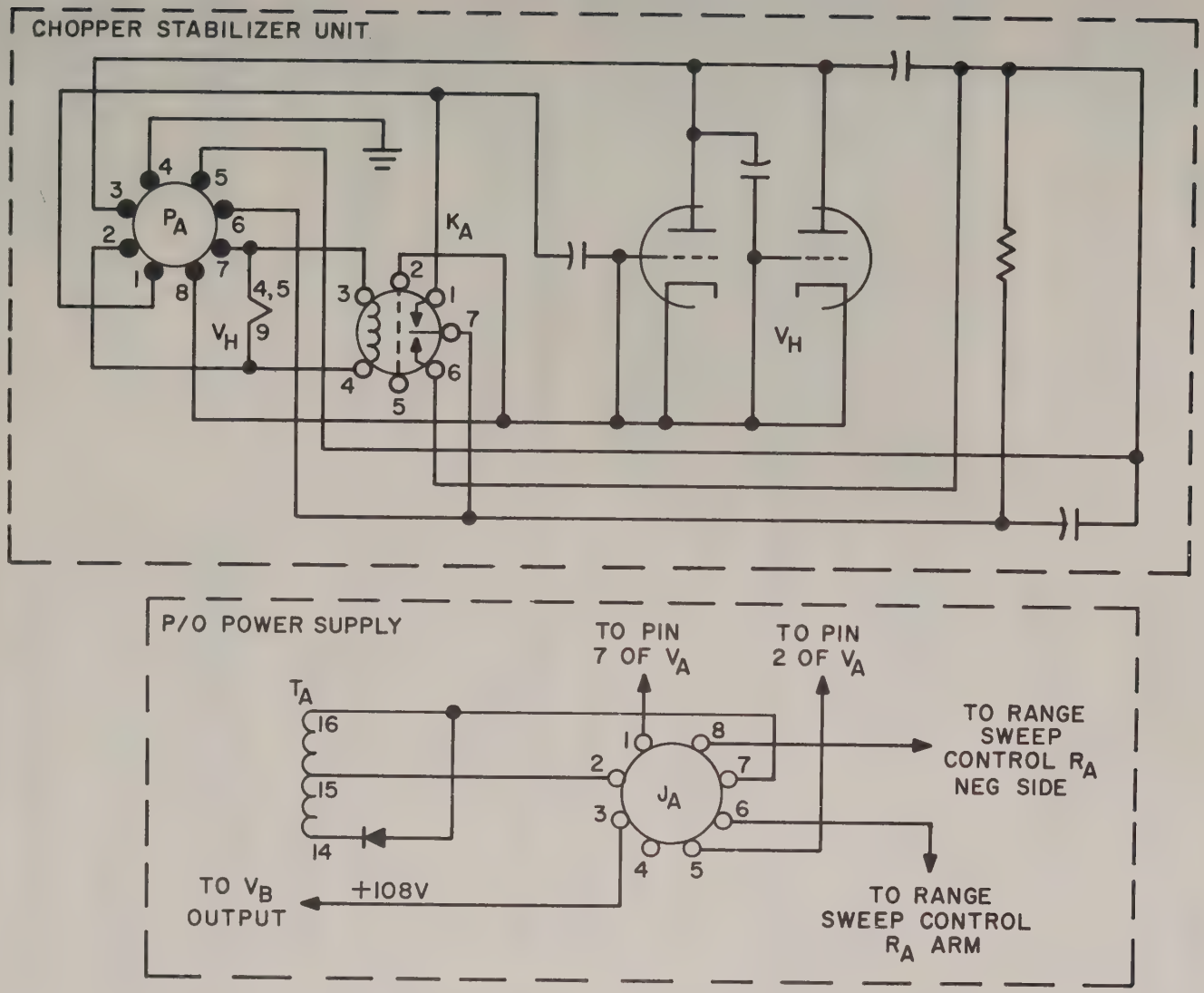


Figure 4-8. Chopper Stabilizer Circuit, Simplified Partial Schematic

SECTION 5
MAINTENANCE

5-1. GENERAL.

This section contains adjustment, calibration, and troubleshooting procedures for the power supply.

NOTE

Refer to the inside front cover of this manual for the WARRANTY under which this equipment is sold.

5-2. NULL ADJUSTMENT.

After replacement of any component in the power-supply control circuitry, check null balance of the balanced input detector as follows:

a. Connect a jumper between (+) and (-) output binding posts.

b. Set Range Selector switch to uA X1-1 setting, (lowest range position) and rotate Range Sweep control clockwise to maximum setting.

c. Connect a voltmeter set for 0- to 1-vdc range between (-) and MOD binding posts.

d. Set DC switch to on position.

e. Adjust NULL control (screwdriver adjust) until voltmeter indicates zero.

5-3. FILAMENT REGULATOR ADJUSTMENT.

Adjust filament regulator as follows:

a. Connect voltmeter between pin 4 or 5 and pin 9 of balanced input detector.

b. Adjust FIL ADJ potentiometer until voltmeter indicates between 5.8 and 6.0 volts.

5-4. CALIBRATION OF OUTPUT CURRENT RANGE SETTINGS.

Calibration of the output current range settings is necessary when -85-volt VR tube, Zener diode between CAL control and Range Sweep control, or any associated voltage divider resistor is replaced. Proceed as follows:

a. Rotate Range Sweep control clockwise to maximum setting.

b. Connect an accurate, high-input-impedance voltmeter between REM and MOD binding posts.

c. Adjust CAL control (screwdriver adjust) for a 5-volt indication on the voltmeter.

NOTE

Accuracy of calibration depends on accuracy of voltmeter used. Tolerance of range selector sample resistors is $\pm 1\%$; therefore, a $\pm 2\%$ meter will insure a maximum tolerance of $\pm 3\%$ of output current range settings (at maximum Range Sweep control setting).

5-5. RIPPLE MEASUREMENT.

Figure 5-1 shows the connections and procedure used for measurement of ripple in the power supply output. Lead wires should be as short as possible. The voltmeter should be completely shielded and battery operated to avoid the injection of extraneous ripple. Load and sample resistor values are selected to produce the minimum compliance voltage in accordance with the voltage compliance graph (see figure 1-2) when the Range Selector switch is set to uA X10-2.2 and the range Sweep control is set to maximum. The resistor values should change as required to develop the specified compliance for other Range Selector switch settings. The value of the load resistor is equal to the minimum compliance voltage divided by the Range Selector switch setting. The value of the sample resistor is calculated for a 5-volt drop. For a 50-volt compliance, the load-to-sample resistor ratio will be 10 to 1; for 100 volts, it will be 20 to 1.

5-6. TROUBLESHOOTING PROCEDURES.

The following procedures may be used as a guide for repairing constant-current power supplies.

5-7. Preliminary Inspection. Inspect the equipment as follows:

a. Examine unit visually for obvious troubles, such as broken wires or components.

b. Remove all pluck-out tubes and transistors, and turn VOLTAGE LIMITER control (if supplied) to maximum setting.

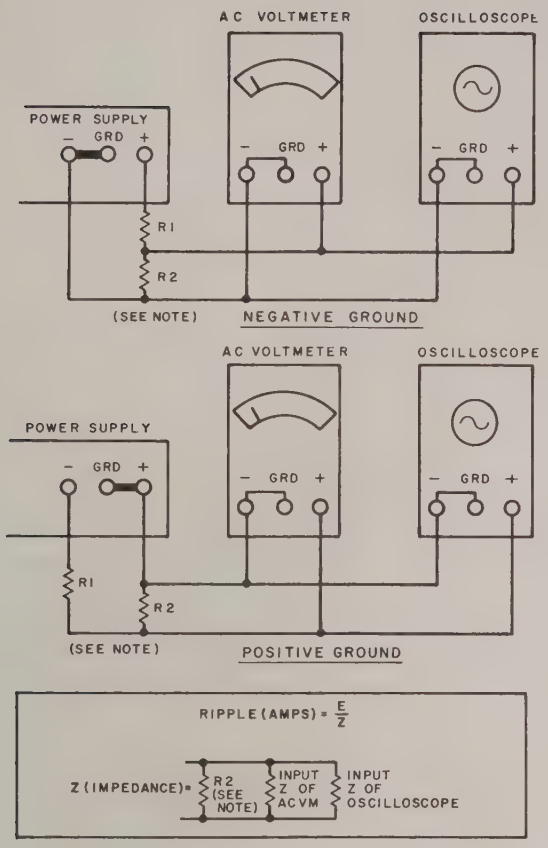
c. Connect a dc voltmeter across filament regulator (from collector of EM101 transistor to pin 9 of error detector tube).

d. Set Variac to 5 volts ac.

e. Set LINE switch and DC switch to on position.

CAUTION

Be extremely careful when servicing this power supply. Dangerous voltages can be developed from the low line voltage.



NOTE

RANGE	1 UA	2.2UA	5 UA	10UA	22 UA	50UA	100UA	220UA	500UA	1 MA	2.2MA
R1 (OHMS)	100M	47M	20M	10M	4.7M	2M	1M	470K	200K	100K	47K
R2(OHMS)	5 M	2.27M	1 M	500K	227K	100K	50K	22.7K	10K	5K	2.27K

RANGE	5MA	10MA	22MA	50MA	100MA	220MA	300MA	500MA	1A	2A	3A
R1(OHMS)	20K	10K	4.7K	2K	1K	470	330	200	100	50	33
R2(OHMS)	1K	500	227	100	50	22.7	16.6	10	5	2.5	1.67

Figure 5-1. Set-up for Ripple Measurement

f. Use a multimeter to check voltages across all electrolytic capacitors. Make any necessary repairs or replacements.

NOTE

If unit has time-delay relay, it must be actuated manually to check voltages across screen voltage capacitor and main power capacitor.

g. Set Variac for 125 volts ac. If unit has a time-delay relay, allow time for relay to actuate.

h. Check voltage across all electrolytic capacitors for proper value and to be sure that no capacitor is operating above its rating.

5-8. Checking Filament Regulator. Check filament regulator as follows:

a. Plug in 2N1372 transistors that were removed from filament regulator section (refer to paragraph 5-7b). These must be 25-volt, PNP, medium Beta transistors, or equivalent.

b. Plug in 12AY7 error detector (input) tube.

c. Connect a dc voltmeter across filament regulator (from collector of EM 101 transistor to pin 9 of error detector tube).

d. Set LINE switch to on position, and set Variac for 105 volts ac. Dc voltmeter should indicate approximately 10 ±0.5 volts. If voltmeter indication is not as specified, disconnect voltmeter from pin 9 of error detector and connect it to pin 4 or 5.

e. Set Variac for 125 volts ac. Dc voltmeter should indicate approximately 12.5 ±0.5 volts. If voltmeter indication is not as specified, check wiring from dc connections to filter of dc voltage filament regulator. Make any necessary repairs.

f. Connect dc voltmeter across filament of error detector (pin 9 to pin 4 or 5).

g. Adjust Variac for a dc voltmeter indication of 5.8 to 6 volts. If satisfactory adjustment cannot be made, proceed as follows:

(1) Remove one end of 30-ohm resistor in parallel with EM101 transistor.

(2) Remove two 2N1372 transistors. Filament voltage should fall to zero. If it does not, check filament regulator section for proper connections, and check EM101 transistor for short.

(3) Replace first 2N1372 (driver) transistor. Filament voltage should rise to maximum input voltage. If it does not, check replaced 2N1372 transistor.

(4) Replace second 2N1372 transistor. If regulator does not operate, check second transistor. Make any necessary repairs.

h. Vary line voltage from 105 to 125 volts ac. Filament regulator voltage should not vary more than 150 millivolts.

i. Set LINE switch to off position.

5-9. Checking Positive and Negative Supply Voltages. If power supply incorporates a chopper stabilizer, remove chopper module, and place a short between pin 5 and pin 6 of chopper stabilizer socket.

a. Plug in gas regulator tubes (two OA2's and one 85A2 for C612 and C624; for all other models two OA2's, two OB2's, and one 85A2).

b. Set LINE switch to on position.

c. Check that all three gas regulator tubes glow. Then vary line voltage from 100 to 130 volts ac. Gas regulator tubes should continue to glow.

d. If any gas regulator tubes do not glow, one of the following probably applies:

(1) Tube has abnormally high starting voltage. Check voltage across tube. If operating voltage is higher than normal, replace tube.

(2) Incorrect wiring has partially or completely shorted tube. In this case, voltage across tube will be abnormally low. Check wiring and make necessary repairs.

(3) Socket may be improperly soldered. Check voltage across tube from copper side of PC board, and check voltage across tube by removing tube and inserting probe in socket holes. If voltages do not match, socket is probably improperly soldered.

e. Set LINE switch to off position, and make necessary repairs.

5-10. Preliminary Balancing of Amplifier. Proceed as follows:

a. Set Range Selector switch to REM position.

b. Connect jumper between (+) and REM terminals, and connect jumper between (-) and MOD terminals.

c. Plug in 2N2191 amplifier transistors.

d. Connect dc voltmeter between pin 1 of 6AU6 tube (pin 4 of 6842 tube for models of 1000 or more volts compliance, such as C638) and REM terminal. (Use probes in tube socket and at REM terminal).

e. Set LINE switch to on position.

f. After equipment has warmed up for about 15 minutes, rotate NULL control from maximum to minimum (fully clockwise to fully counterclockwise). Dc voltmeter indication should vary from about -70 volts to about -100 volts. If voltage does not vary as specified, check the input stage and the transistor amplifier stage as follows:

(1) Remove 12AY7 tube and 2N2191 amplifier transistors, and make a point-to-point check between sockets and PC board copper to be sure that sockets are properly soldered.

(2) Check wiring from NULL control to PC board.

(3) Check wiring from grids of 12AY7 tube to MOD and (-) output terminals.

(4) Check 2N2191 amplifier transistors.

(5) Check 830K-ohm and/or 330K-ohm collector resistors of 2N2191 amplifier for proper value.

(6) Check 22K-ohm plate resistors of 12AY7 tube and 22K-ohm emitter resistor of 2N2191 amplifier transistors.

g. Set LINE switch to off position, and make necessary repairs.

h. Plug in 6AU6 tube (6842 for models of 1000 or more volts compliance), and connect dc voltmeter between pin 5 of 6AU6 tube (6842 for models of 1000 or more volts compliance) and REM terminal.

i. Set LINE switch to on position.

j. Vary NULL control from maximum (fully clockwise) to minimum (fully counterclockwise). Voltmeter indication should vary from about -40 volts to +150 volts over a very small range of NULL control rotation. If the voltage does not vary as specified, check 6AU6 tube (6842 for models of 1000 or more volts compliance) as follows:

(1) Check that tube socket is properly soldered.

(2) Check value of plate resistor and grid divider resistors.

k. For units that have a cathode follower between final amplifier and series dropping tubes, plug in 12AX7 cathode follower. Then proceed as follows:

(1) Connect dc voltmeter between REM terminal and cathode of 12AX7 cathode follower.

(2) Set LINE switch to on position, and wait for equipment to warm up.

(3) Rotate NULL control from maximum to minimum. Voltage should vary from about -40 volts dc to about +150 volts dc over a very short rotation of NULL control. If voltage does not vary as specified, 12AX7 cathode follower is defective. In this case, check 12AX7 tube, and associated wiring and components.

(4) Turn LINE switch to off position, and make any necessary repairs.

l. Set LINE switch to off position, and make necessary repairs.

m. Plug in one series tube and remove jumper from (+) and REM terminals.

n. If power supply has no meters, connect a dc voltmeter between (+) and REM terminals.

o. Set LINE switch to on position and wait about 15 minutes for equipment to warm up.

p. Rotate NULL control from maximum to minimum (fully counterclockwise). Dc voltmeter indication should vary from zero or slightly negative to maximum rating of power supply output.

q. If voltage does not vary as specified in p above, check series deck and wiring for the following:

(1) Defective dc fuse.

(2) Defective series tube.

(3) Defective wiring.

(4) Poor solder joints.

(5) Incorrect component.

r. Set LINE switch to off position, and make any necessary repairs.

s. Replace all series tubes, and repeat steps 1 through q.

t. Set LINE switch to off position, make additional repairs, if required, and remove jumpers from output terminals.

5-11. Checking Range Selector. Proceed as follows:

a. Set power supply current controls for 10-milliampere output.

b. Connect jumper between (+) and (-) output terminals.

c. Connect bucking meter between (-) and MOD terminals.

d. Set LINE switch to on position and allow about 15 minutes for equipment to warm up.

e. Set DC switch to on position, and adjust NULL control for a bucking meter indication of zero.

f. Set DC switch to off position, and turn Range Sweep control to maximum clockwise setting.

g. Connect a high-impedance dc voltmeter (0.5% accuracy) between REM and MOD terminals.

h. Adjust CAL control for an indication of 5 volts dc on the meter.

i. Remove jumper from (+) and (-) terminals and substitute an ammeter (multimeter).

j. Set DC switch to on position, and check current at all Range Selector switch settings for correct value. This procedure will check out the value and location of all Range Selector resistors.

5-12. Checking Voltage Limiter. Proceed as follows if the power supply is supplied with a LIMITER VOLTS control:

a. Check associated wiring, particularly the limiter potentiometer and the CAL potentiometer.

b. Plug in the limiter components (two 2N398 transistors, or one 2N398 transistor and a 12AX7 tube).

c. Disconnect any loads from output terminals. Set LINE switch to on position and wait about 15 minutes for equipment to warm up.

d. Set DC switch to on position, and turn LIMITER VOLTS control to maximum clockwise setting. Voltage (as indicated by D. C. VOLTS meter) should rise to maximum.

e. Turn LIMITER VOLTS control slowly towards zero. Voltage should begin to drop when LIMITER VOLTS control reaches 90 degrees of rotation.

f. Turn LIMITER VOLTS control to the two-thirds counterclockwise position. If voltage has not dropped, the limiter is defective, and the trouble is probably one of the following:

(1) Reference resistor not installed.

(2) Diode switch between 6AU6 tube (6842 for models of 1000 or more volts compliance) and collector of limiter transistor not operating.

(3) Defective limiter transistor.

g. Set LINE switch to off position, make necessary repairs, and recheck (steps c through f above).

h. With limiter operating, check for oscillation. if there is oscillation, one or more of the following may be required:

(1) Change of capacitor across collector resistor of limiter transistor.

(2) Insertion of capacitor between positive output and arm of control potentiometer.

(3) Insertion of capacitor between positive output and collector of transistor that drives tube 6AU6 (6842 for models of 1000 or more volts compliance).

5-13. Checking Chopper Stabilizer. If the power supply has provision for a chopper stabilizer, proceed as follows:

a. With power supply in operation, remove short from pins 5 and 6 of chopper socket.

b. Check wiring to be sure that 120K-ohm resistor and two 25-uf, 25-volt capacitors are installed.

c. Plug in chopper module, and plug 12AX7 tube and mechanical chopper into module.

d. Set LINE switch to on position, and wait approximately 15 minutes for equipment to warm up.

e. Connect ammeter between (+) and (-) terminals.

f. Adjust Range Selector switch for 10-milliampere output.

g. Connect bucking meter between (-) output terminal and arm of Range Sweep control.

h. Set DC switch to on position, and turn Range Sweep control to maximum clockwise setting.

i. Wait a few minutes until chopper has settled. Then check bucking meter. Meter indication should be close to zero.

j. Rotate NULL control back and forth. Bucking meter should indicate abrupt change, but should return to within a few millivolts of previous indication.

k. If indications are not as specified in steps i and j above, one or more of the following is probably causing the trouble:

(1) Defective mechanical chopper.

(2) Defective 12AX7 tube in chopper.

(3) Defective filter capacitor in chopper.

(4) Defective wiring.

l. After checking chopper operation, remove chopper module, replace short between pins 5 and 6 of chopper socket, and reset NULL control for zero on bucking meter. Then remove short from pins 5 and 6 of socket, and replace chopper module.

NOTE

Power supply should always operate with minimum output from chopper.

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